# Technical Assistance Services *for* Communities

## Understanding Units of Measurement

### Introduction

Technical environmental reports that discuss soil, water, or air contamination often report numerical values in units unfamiliar to the general public. The different units of measurement can be confusing. This fact sheet helps people understand these measurement units. Examples of typical units of measurement are listed below.

| Numbers | Mass |
|---|---|
| Million = 1,000,000 | 28 grams = about 1 ounce |
| Billion = 1,000,000,000 | 1 kilogram (kg) = 1,000 grams |
| Trillion = 1,000,000,000,000 | 1 milligram (mg) = 1/1,000 gram = 0.001 gram |
| One millionth = 0.000001 | 1 microgram (µg) = 1/1,000,000 gram = 0.000001 gram |
| One billionth = 0.000000001 | 1 nanogram (ng) = 1/1,000,000,000 gram = 0.000000001 gram |
| One trillionth = 0.000000000001 | 1 picogram (pg) = 1/1,000,000,000,000 gram = 0.000000000001 gram |

Volume
One liter (L) = 1.06 quarts
One cubic meter ($m^3$) = 35.31 cubic feet ($ft^3$)
One cubic meter ($m^3$) = 1,000 liters (L)
One liter (L) = 1,000 milliliter (ml) = 1,000 cubic centimeters

### Concentrations in Soil and Water

Concentrations of chemicals in soil are typically measured in units of the mass of chemical (milligrams, mg, or micrograms, µg) per mass of soil (kilogram, kg). This is written as mg/kg or µg/kg. Sometimes concentrations in soil are reported as parts per million (ppm) or parts per billion (ppb). Parts per million and parts per billion may be converted from one to the other using this relationship: 1 part per million = 1,000 parts per billion.

For soil, 1 ppm = 1 mg/kg of contaminant in soil, and 1 ppb = 1 µg/kg. A measurement of 6 mg/kg is the same as 6 ppm or 6,000 ppb, which is equal to 6,000 µg/kg.

Concentrations of chemicals in water are typically measured in units of the mass of chemical (milligrams, mg, or micrograms, µg) per volume of water (liter, L, l). Concentrations in water can also be expressed as parts per million (ppm) or parts per billion (ppb). Parts per million and parts per billion may be converted from one to the other using this relationship: 1 part per million = 1,000 parts per billion.

**Visualization: PPB and PPM**

One part per billion (ppb) in water is like one drop in one billion drops of water or about one drop of water in a swimming pool. One part per million (ppm) is about one cup of water in a swimming pool.

For water, 1 ppm = about 1 mg/L (also written as mg/l) of contaminant in water, and 1 ppb = 1 µg/L (also written as µg/l). A measurement of 6 mg/L is the same as 6 ppm or 6,000 ppb, which is equal to 6,000 µg/L.

Occasionally, concentrations of chemicals in water may be written as grams per cubic meter ($g/m^3$). This is the same as grams per 1,000 liters, which may be converted to milligrams per liter (mg/L). Therefore, 1 $g/m^3$ = 1 mg/L = 1

ppm. Likewise, one milligram per cubic meter ($mg/m^3$) is the same concentration in water as one microgram per liter (µg/L), which is about 1 ppb.

**Concentrations in Air**

Concentrations of chemicals in air are typically measured in units of the mass of chemical (milligrams, micrograms, nanograms or picograms) per volume of air (cubic meter or cubic feet). However, concentrations may also be expressed as parts per million (ppm) or parts per billion (ppb) by using a conversion factor. The conversion factor is based on the molecular weight of the chemical and is different for each chemical. Also, atmospheric temperature and pressure affect the calculation.

Typically, conversions for chemicals in air are made assuming a pressure of 1 atmosphere and a temperature of 25 degrees Celsius. For these conditions, the equation to convert from concentration in parts per million to concentration in milligrams per cubic meter ($mg/m^3$) is:

Concentration ($mg/m^3$) = 0.0409 x concentration (ppm) x molecular weight

To convert from $mg/m^3$ to ppm, the equation is:

Concentration (ppm) = 24.45 x concentration ($mg/m^3$) ÷ molecular weight

The same equations may be used to convert micrograms per cubic meter ($\mu g/m^3$) to parts per billion (ppb) and vice versa:

Concentration ($\mu g/m^3$) = 0.0409 x concentration (ppb) x molecular weight

Or, concentration (ppb) = 24.45 x concentration ($\mu g/m^3$) ÷ molecular weight

*Note:* Sometimes chemical concentrations in air are given in concentration per cubic feet ($ft^3$) instead of concentration per cubic meter ($m^3$). The conversion from cubic feet to cubic meter and vice versa is 1 $ft^3$ = 0.02832 $m^3$ and 1 $m^3$ = 35.31 $ft^3$.

**Conversion Example**

The molecular weight of benzene is 78. If the concentration of benzene in air is 10 $mg/m^3$, convert to the units of ppm by multiplying 24.45 by 10 $mg/m^3$ and dividing by 78, which equals 3.13 ppm.

**Radioactivity**

Radioactivity is the process of one element decaying to form another element. This rate of decay (activity) is commonly measured in units of picocuries (pCi) or millibecquerels (mBq).

1pCi = 37 mBq

Picocuries or millibecquerels are related to the decay rate, or disintegration rate of an element, as follows:

1 picocurie = 2.2 disintegrations per minute (dpm)  37 mBq = 2.2 disintegrations per minute

Therefore, 1 pCi or 37 mBq is equivalent of 2.2 atoms of one element decaying into another element. To put this number in perspective, the average indoor radon level is 1.3 pCi/L and average outdoor radon level is 0.4 pCi/L Radon is a radioactive gas that occurs naturally. Some radiation monitors measure radioactivity in counts per minute (cpm), usually counts of alpha particles or beta particles. The equipment does not measure the actual disintegrations per minute at the source of the radioactivity. Calibrating and converting cpm to dpm is specific for each instrument.

**Measuring the Effect of Radioactivity**

The measure of radioactivity in pCi or mBq is used in complex calculations to determine the amount of ionizing radiation that human tissue will absorb when exposed to specific radioactive materials. This section describes units

associated with measuring the effect of radioactivity on human tissue. It is adapted from information provided by the Nuclear Regulatory Commission (http://www.nrc.gov/about-nrc/radiation/health-effects/measuring-radiation.html). There are four different but interrelated units of measure: radioactivity, exposure, absorbed dose and dose equivalent. These can be remembered by the mnemonic **R-E-A-D**, as follows, with both common (British, e.g., Ci) and international (metric, e.g., Bq) units in use:

**R →R**adioactivity refers to the amount of ionizing radiation released by a material (charged particles). Whether it emits alpha or beta particles, gamma rays, x-rays or neutrons, a quantity of radioactive material is expressed in terms of its radioactivity (or simply its activity), which represents how many atoms in the material decay in a given time period. The units of measure for radioactivity are the curie (Ci) and becquerel (Bq) or picocurie (pCi) and millibecquerel (mBq). [1 Ci=0.037 Bq]

**E →E**xposure describes the amount of radiation traveling through the air. It is a measure of the ionizations of the molecules in a mass of air. Many radiation monitors measure exposure. The units for exposure are the roentgen (R) and coulomb/kilogram (C/kg). R can only be used to describe an amount of gamma and x-rays, and only in air. One R is equal to depositing in dry air enough energy to cause 0.000258 coulombs per kilogram (C/kg) of energy. [1 R = 0.000258 C/kg]

**A →A**bsorbed dose describes the amount of radiation absorbed by an object or person (that is, the amount of energy that radioactive sources deposit in materials through which they pass). The units for absorbed dose are the radiation absorbed dose (rad) and gray (Gy). One rad equals the absorption of 100 ergons (ergs) of energy per gram of material. One gray equals the absorption of 1 Joule (J) of energy per kilogram of material.

1 rad = 100 ergs per gram  1 J = 10,000,000 ergs
1 Gy = 1 J/kg  1 Gy = 100 rad

**D →D**ose equivalent (or effective dose) combines the amount of radiation absorbed and the medical effects of that type of radiation. For beta and gamma radiation, the dose equivalent is the same as the absorbed dose. By contrast, the dose equivalent is larger than the absorbed dose for alpha and neutron radiation, because these types of radiation are more damaging to the human body. Units for dose equivalent are the roentgen equivalent man (rem) and sievert (Sv). Biological dose equivalents are commonly measured in 1/1000th of a rem (known as a millirem or mrem). [1 Sv = 100 rem; 1 mSv = 100 mrem]

Table 1 shows some typical radiation doses in the United States.

**Table 1: Effective Radiation Doses in the United States**

| Source | Dose Equivalent | |
|---|---|---|
| U.S. Average External Background Radiation | 0.60 mSv per year | 60 mrem per year |
| Natural K-40 and Other Radioactivity in Body | 0.4 mSv per year | 40 mrem per year |
| Air Travel Round Trip (New York to Los Angeles) | 0.05 mSv | 5 mrem |
| Chest X-Ray Effective Dose | 0.10 mSv per view | 10 mrem per view |
| Radon in the Home (variable) | 2.00 mSv per year | 200 mrem per year |
| Man-Made (e.g., medical x-rays) (average) | 0.60 mSv per year | 60 mrem per year |
| *Source:* Adapted from information provided by the Health Physics Society: http://hps.org/publicinformation/ate/faqs/radiation.html. | | |

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The Technical Assistance Services for Communities (TASC) contract provides supplemental, non-advocacy technical assistance services at no cost to communities to empower them to substantively participate in addressing environmental issues and actions which impact their community.